Z. Säugetierkunde 59 (1994) 209–217

ISSN 0044-3468

Reproductive biology and population structure of *Rattus rattus* in Rawalpindi, Pakistan

By J. E. Brooks, E. Ahmad, and I. Hussain

Denver Wildlife Research Center, Denver, Colorado, USA and Vertebrate Pest Control Project, National Agricultural Research Centre, Islamabad, Pakistan

Receipt of Ms. 4. 11. 1993
Acceptance of Ms. 24. 3. 1994

Abstract

Studied the breeding biology and population structure of roof rats (*Rattus rattus*) in the wholesale grain and commodities market in Rawalpindi, Pakistan. Rats were trapped from the grain market monthly for 14 months. We necropsied 2327 rats, comprising 1175 males and 1152 females, essentially a 1:1 sex ratio. Males were found fertile in every month, with no significant seasonal differences; females were pregnant in every month, and the adjusted frequency of pregnancy averaged 39.8 %. Litter size during the last quarter of pregnancy averaged 6.1 ± 1.7 Standard Deviation (SD). Based upon primiparous and multiparous females, we calculated that an average adult female had 1.8 pregnancies. Average production of young was 10.9/female (6.1 × 1.8). Immature animals (weaned, but not sexually mature) constituted 13.1 % of the total collection, and recruitment was continuous during the study, indicating high mortality among nestling and weanling rats. Numerous wounds and scars on adults of both sexes indicated a high degree of social strife and aggression among the rats.

Introduction

The rat commonly found in grain storage facilities, wholesale commodities markets, cities, towns, and farm houses in Pakistan is the roof rat (*Rattus rattus*). Taber et al. (1967) refer to the subspecies in the Indus Plains and upland areas in northern Pakistan as *R. rattus rufescens* (Gray), a brownish-gray-backed form with a venter either creamy white or light gray with a rufous tint. The typical mammary formula is 2 + 3 = 10, with an occasional pairing of the postaxial mammae to give a 3 + 3 = 12 formula.

Previous studies dealing with the reproductive biology and population dynamics of this subspecies in similar habitats gave somewhat contradictory findings. Beg et al. (1983) in Faisalabad, Pakistan, found that trapping success was lowest in winter and peaked in summer: pregnancy occurred only in 10 months of the year and averaged 45 % during the study; the proportion of young was highest in the winter and averaged 31 % of the collections during the year. Rana et al. (1983) in Jodhpur, India, found that females were pregnant throughout the year; the annual frequency of pregnancy was 25.5 %; the proportion of young averaged 54 % and was lowest from January to April. Additional information on the reproductive biology and population dynamics of this subspecies is needed to use control methods with proper timing. Thus, we carried out a 14-month study of the roof rat population in the wholesale grain market in Rawalpindi, Pakistan.

Material and methods

Description of the grain shops

The Rawalpindi market consists of several hundred dealers occupying ground floor, small (25 m^2–45 m^2 floorspace) shops, 40–50 years old, with capacities for 500–800 bags of commodities (50–80 metric tons). None of the shops are ratproof. The main commodity is rice; other foods available are

U.S. Copyright Clearance Center Code Statement: 0044-3468/94/5904-0209 $ 02.50/0

lentils, grams, sorghums, wheat flour, and groundnuts. The amounts of grains sold annually vary from 1,000 bags to 60,000 bags (Brooks et al. 1987).

Trapping

Commercial wire-mesh live traps (41 × 14 × 14 cm) and Sherman galvanized steel traps (25 × 7.5 × 8 cm) were used. The smaller traps were more suitable for smaller rats. We baited the traps with fresh seasonal vegetables or fruit, which the rats readily accepted, and trapped for 4 consecutive nights each month from April 1987 through May 1988 by setting ten wire-mesh traps and five Sherman traps in each of eight shops. Each month we selected eight different shops, four on each side of the roadway, to minimize invasion from surrounding shops and to avoid the effect of removal trapping on population size. The Sherman traps were not available during the first 2 months of the study.

Necropsy procedure

After using chloroform to kill rats in the laboratory, we necropsied 2327 rats. Slight discrepancies in totals resulted when all data were not taken on some rats. We weighed and measured each animal before necropsy and recorded reproductive data: for females, this included the condition of the vaginal orifice (perforate or not), condition of the uterus (nulliparous, pregnant, placental scars), condition of the ovaries (corpora lutea visible or not), number of embryos, their crown-rump length, and whether any were resorbing. For males, we recorded the position (abdominal or scrotal), length, and weight of testis, and whether the tubules of the cauda epididymis were visible or not. We recorded the number of scars, wounds, fractures, and missing limbs on the trapped rats.

We classified animals as sexually mature by calculating the 50 % points at which females showed visible corpora lutea and males showed visible tubules in the cauda epididymis (Davis 1964). Animals meeting or exceeding these 50 % points in body weight (BW) and in head and body length (HBL) were adults; all others were immatures.

Using Harrison's (1952) methods to compare rat populations, we calculated the "embryo rate" (the crude pregnancy rate × the unadjusted embryo number = the number of embryos per 100 females of all sizes) and the "reproduction rate" (the number of embryos per 100 head of population, males and females). We believe these rates to be more indicative of a population's reproductive potential than the reproductive rate as defined in Southwick's (1966) procedure in which he used the yearly production per female, calculated from the average litter size and the incidence of pregnancy (yearly pregnancies per female). The incidence of pregnancy is an artificial figure indicating the number of times a female rat could be pregnant during a year; actually very few female rats live a year, so the incidence of pregnancy gives an overestimation of potential production. We used 16 days as the period of visible pregnancy in the roof rat (Southwick 1966).

Population estimates

Monthly population estimates were calculated from the linear regression of cumulative captures on daily captures (Blower et al. 1981). Because captures were taken from a different set of eight grain shops each month, we cannot generalize much about seasonal population changes. We compared the number of animals captured with population estimates to see if there was a correlation.

Results

Characteristics of the sample

The proportion of males to females was 50.5:49.5, which does not differ significantly from a 1:1 sex ratio. Males grew to a greater body weight than did females, but did not exceed females in head and body length (Tab. 1). There was no significant difference in mean body weight at equivalent HBL's between sexes below 160 mm; above that point, males were significantly heavier ($P = 0.01$). Males predominated in the largest size classes. The largest male weighed 273.5 g and measured 214 mm. The heaviest female weighed 246.8 g and measured 199 mm; however, the longest female measured 215 mm. The mean weight of pregnant females was 163.2 g ± 29.5, ranging from 84.4 to 246.8 g.

Table 1. **Head and body length (HBL), body weight (BW), and sex ratio of *Rattus rattus* from Rawalpindi, Pakistan**

(Mean ± SD)

Head and body length size classes (mm)	Males		Females		
	Number of animals	Body weight (g)	Number of animals	Body weight (g)	*P*
80– 89	1	18.5	3	18.0 ± 1.7	ns
90– 99	12	24.6 ± 2.9	13	23.9 ± 3.5	ns
100–109	18	34.2 ± 3.8	23	32.9 ± 4.3	ns
110–119	12	40.3 ± 6.6	18	44.1 ± 6.9	ns
120–129	29	51.8 ± 10.2	27	53.7 ± 7.2	ns
130–139	21	67.8 ± 11.5	29	65.8 ± 10.9	ns
140–149	53	88.6 ± 12.5	73	86.5 ± 11.0	ns
150–159	102	106.0 ± 13.7	102	103.3 ± 13.2	ns
160–169	158	127.9 ± 17.5	192	122.9 ± 14.4	0.01
170–179	296	150.1 ± 18.5	308	146.0 ± 17.4	0.01
180–189	286	170.9 ± 20.1	235	166.1 ± 18.9	0.01
190–199	150	191.8 ± 23.1	109	176.6 ± 18.3	0.01
200–209	34	205.0 ± 19.9	18	181.9 ± 23.6	0.01
210–219	3	231.3 ± 43.2	2	206.4 —	—
Totals	1175		1152		
Means, BW	146.8 ± 51.3		138.1 ± 46.7		
Means, HBL	171.4 ± 21.3		167.9 ± 22.0		

Reproduction

We defined mature females as those that weighed ≥80 g or were ≥139 mm in HBL; mature males weighed ≥96 g or were ≥152 mm in HBL. We observed fertile males in every month of the year. Male fertility begins when testis weight reaches 0.7–0.8 g and a length of 16–17 mm. Many males with testis smaller than these nevertheless were observed to be scrotal. There was little seasonal fluctuation in mean testis weights when adjusted for mean body weights (Fig. 1).

The adjusted frequence of pregnancy, as judged by visible pregnancy in all adult females (≥80 g BW), ranged from 30 % in April to 58 % in July (Fig. 2). The frequence of

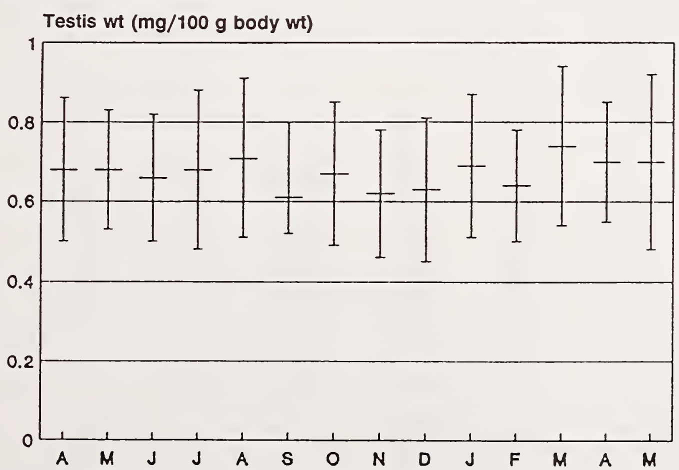

Fig. 1. Mean testis weights (± SD) in male *R. rattus* adjusted for monthly body weights

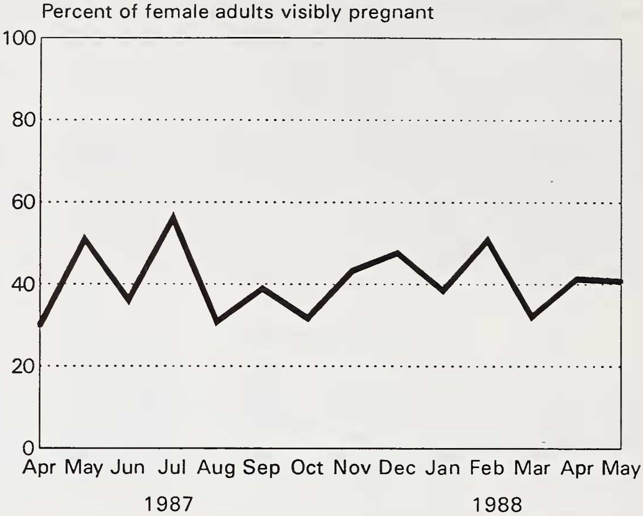

Fig. 2. Percentage of visible pregnancies monthly in adult female *R. rattus*

pregnancy for the entire study was 39.8 %. The smallest pregnant female was 145 mm HBL, but most pregnancies occurred in females ≥ 150 mm HBL and ≥ 100 g body weight (Tab. 2).

Primigravid females constituted 53.7 % of all pregnancies (Tab. 3). The 1:0.78 ratio between females pregnant for the first time and those bearing their second litter indicates that, on the average, primigravid females have a 78 % chance of living long enough to have a second pregnancy.

Litter size

The number of embryos per female ranged from 1 to 16, and 80 (3.0 %) of the total of 2682 embryos were resorbing. We examined litter size by embryo size (CR = crown-rump length), roughly corresponding to the second, third, and fourth quarters of pregnancy, and

Table 2. **Relationship of HBL and BW to visible pregnancy in female *R. rattus* from Rawalpindi**

Body size class (mm)	Number examined	Pregnant Number	Pregnant %	Body weight class (g)	Number examined	Pregnant Number	Pregnant %
<140[a]	113	0	0.0	<80[a]	131	0	0.0
140–149	73	4	5.5	80– 99	88	5	5.7
150–159	102	29	28.4	100–119	116	24	20.7
160–169	192	88	45.8	120–139	191	64	33.5
170–179	308	123	39.9	140–159	229	93	40.6
180–189	235	103	43.8	160–179	214	105	49.1
190–199	109	53	48.6	180–199	117	66	56.4
200–209	18	5	27.8	200–219	54	37	68.5
210–219	2	1	50.0	220–239	12	12	100.0
Total rats							
≥ 140 mm	1039						
≥ 80 g					1021		
Total/percent rats pregnant		406	39.1			406	39.8

[a] Immatures.

Table 3. **Corpora lutea and parity in *R. rattus***

HBL size class (mm)	Number examined	Corpora lutea visible	Nulli-parous	Primi-gravid	Multi-gravid	Parous Non-gravid with scars 1 set	2 sets	3 sets
80– 89	3	0	3	0	0	0	0	0
90– 99	13	1	13	0	0	0	0	0
100–109	23	1	23	0	0	0	0	0
110–119	18	1	18	0	0	0	0	0
120–129	27	6	27	0	0	0	0	0
130–139	29	12	29	0	0	0	0	0
140–149	73	58	63	4	0	6	0	0
150–159	99	95	51	24	5	19	0	0
160–169	188	186	34	69	19	53	13	0
170–179	299	293	25	59	64	95	52	4
180–189	228	225	10	42	61	50	58	7
190–199	107	107	5	17	36	17	27	5
200–209	17	15	3	3	2	4	5	0
210–219	2	2	0	0	1	1	0	0
Totals	1126	1002	304	218	188	245	155	16

found that embryo counts in the second quarter averaged 6.90/female and decreased to 6.09/female in the last quarter. This decrease indicated an intrauterine loss of 0.81 embryo, a mortality of 11.7 % of embryos from all causes. Litter size changed with increasing body size of the female from 5.7 ± 1.8 (in females 150–159 mm HBL) to 7.4 ± 2.0 (in females 190–199 mm HBL).

Population and age structure

Sex ratios from immature and adult rats were basically alike, although males predominated among the immature rats (142 males to 123 females), but the difference was not significant ($X^2 = 1.36$, $P = 0.20$). Data for April and May 1987 were not used because the smaller traps suitable for immature rats were not available then.

The recruitment of young animals into the population occurred throughout the year (Tab. 4). We found that recruitment of immatures each month showed a significant correlation with the frequence of pregnancy in the preceding month ($r = 0.742$, $t = 3.5$, $P = 0.005$).

Table 4. **Recruitment of young *R. rattus***

Month	Immatures	Adults	% immatures
Jun.	31	145	17.6
Jul.	22	168	11.6
Aug.	21	108	16.3
Sep.	18	180	9.5
Oct.	14	124	10.1
Nov.	7	126	5.3
Dec.	25	168	12.9
Jan.	17	95	15.2
Feb.	27	133	16.9
Mar.	21	115	15.4
Apr.	15	102	12.8
May	26	158	14.1
Totals	244	1622	13.1

April and May 1987 captures are deleted because small live traps for immature rats were not available in those months.

Population estimates

Except for April 1987, the captures per trap night varied only between 0.24 and 0.41 (Tab. 5). The capture rate and numbers of animals removed were virtually the same in June 1987 and May 1988. This is indicative of stable populations; most differences in population estimates occurred because of trapping vagaries, (e.g., more rats captured on the second or third night, or disturbances in shops that may have affected captures). There was a fair correlation between the number of animals captured and the estimated population (power regression, correlation coefficient = 0.64).

Table 5. **Roof rat captures, trap success, and estimated populations from Rawalpindi**

Month	Captures/day 1	2	3	4	Total captures	Trap nights	Captures/ trap night	Estimated population
Apr. 87	63	59	53	45	220	320	0.69	785
May	45	23	21	21	110	320	0.34	149
Jun.	51	53	39	33	176	480	0.37	389
Jul.	51	57	42	40	190	480	0.40	573
Aug.[a]	43	39	24	23	129	420	0.31	210[a]
Sep.	54	48	52	44	198	480	0.41	1034
Oct.	35	44	29	30	138	480	0.29	455
Nov.	43	40	27	26	136	465	0.29	254
Dec.	46	61	43	43	193	465	0.41	908
Jan. 88	35	34	28	15	112	465	0.24	191
Feb.	41	42	40	37	160	480	0.33	1239
Mar.	36	39	36	25	136	480	0.28	407
Apr.	36	34	31	16	117	465	0.25	211
May	45	50	47	42	184	480	0.38	1850
Totals	624	623	512	440	2199	6280	0.35	8655

[a] 7 shops only.

Table 6. **The frequence of scars, wounds, and missing body parts in *R. rattus***

Disabilities	Females	Males
Part of tail gone	125	194
Wounds on tail	58	76
Fracture of tail	15	17
Swollen tail	4	1
Wounds or abscess on body	20	13
Wounds or swollen legs	5	2
Fracture of hind foot	1	0
Missing hind leg	0	1
Totals	228	304

Intraspecific strife

The most frequently observed evidence of fighting among the rats was that parts of tails were missing (Tab. 6). Wounds on tails were seen next in frequence. In aggressive encounters among rats, the winner quite often bites at the lower back or tail of the loser (personal observation). Fractures and swellings of tails were seen less often. Many females were wounded and had missing body parts (18 % of the total female sample). This is indicative of extreme strife since aggressive exchanges are usually confined to those between males (BARNETT 1963). Altogether, animals bearing evidence of aggressive exchanges were about 23 % of the total collection.

The incidence of injuries increased sharply for rats of both sexes ≥ 150 mm in body size. This could be due to cumulative encounters.

Discussion

We compared our findings with those of two similar studies cited earlier. The sizes of rats at maturity depend on the average body sizes of rats in each population. The average sizes of rats differ in the three populations: Faisalabad females averaged 87 g and males averaged 94 g; Rawalpindi females averaged 138 g and males averaged 147 g. Roof rats from Jodhpur were the smallest, with females averaging 77 g and males 76 g. The average for Jodhpur is low because many immatures were trapped; however, maximum body weights recorded were not notable. Rats from Faisalabad and Rawalpindi were larger, but not necessarily older, than rats from Jodhpur.

Males from Rawalpindi showed little seasonal change in testis weights and were fertile in all months. Sexually active males were seen in all months in Jodhpur, but the proportion of fertile males dropped to low levels in April, July, and September. No data on seasonal fertility in males rats were reported from Faisalabad.

Pregnant females occurred in every month in Rawalpindi and Jodhpur. In Faisalabad, pregnant rats were not seen in November or December. The frequency of pregnancy and ovarian weights varied seasonally in Jodhpur; it was lowest in June and October and highest in July and December. The annual frequency of pregnancy was highest in Faisalabad (46 %), next highest in Rawalpindi (39.8 %), and lowest in Jodhpur (25.5 %).

The comparative litter sizes were similar. In Jodhpur, Faisalabad, and Rawalpindi, they ranged from 6.60 to 6.19. These crude litter sizes, however, are not adjusted to account for the number of embryos actually seen at birth. Often, litter size decreases as pregnancy progresses. Counts taken in the last trimester of visible pregnancy approximate the numbers seen at birth.

We calculated the "embryo rate per 100 of all females" and from this derived the "reproductive rate" (Harrison 1952); this is the number of embryos per 100 head of population (Tab. 7). This rate is highest in rats from Faisalabad and Rawalpindi. This reproductive rate in stable rat populations is sometimes interpreted as a measure of the death rate, since births should equal deaths to maintain stability. However, high mortality in weanlings and juveniles can invalidate this assumption. In that case, the entry of young breeders (recruitment) into the population should be a better measure of the death rate.

Table 7. **Comparative reproductive data and calculated parameters for *R. rattus* from several Asian urban localities**

City	Sex ratio[a]	Crude pregnancy rate	Unadjusted embryo number	Embryo rate[b]	Reproduction rate[c]
Jodhpur	121	25.5	6.60	168	92
Rawalpindi	100	35.2	6.60	232	116
Faisalabad	117	36.1	6.19	223	120

[a] Females/100 males. – [b] Number of embryos for all females in population regardless of size. – [c] Number of embryos for 100 head of population, males and females.

The percentage of immature rats in the several populations was 13 % in Rawalpindi, 31 % in Faisalabad, and 54 % in Jodhpur. We assume that roof rat mortality (in adults) is least in Rawalpindi and greatest in Jodhpur. The reasons for the high recruitment of young rats in Jodhpur are not given by the authors, but may be due, in part, to a relatively harsh environment. In Rawalpindi, the main cause of rat mortality is year-round intraspecific strife.

Despite a high reproductive rate in Rawalpindi roof rats, the low proportion of immatures entering the population indicates high mortality among nestling and weanling rats. This could be due to desertion of litters before weaning (few lactating females were seen) or predation by adult rats.

The differing population strategies are exemplified by the Rawalpindi and Jodhpur rat populations. Whereas Rawalpindi relies upon a high reproductive rate to offset high mortality in immatures to maintain the population. Jodhpur rats rely upon a high recruitment of immatures into the population to offset the apparent high mortality in adult rats. Pregnancies at Jodhpur remain at a rather lower level than at either Rawalpindi or Faisalabad.

The implications for management of Rawalpindi rat populations are not promising. Since juvenile mortality is already high, efforts to increase adult mortality with poisons would tend to decrease the pressure on the juveniles. The birth rate would be adjusted by the rats following population reduction to compensate for mortality, and both frequence of pregnancy and litter size would be expected to increase.

More effective control measures would be those that change the environment. Rat-proofing of grain shops, though difficult, would bring about population decreases. There are numerous holes in walls between adjoining shops that could be filled to stop rat movements. Grain shop sanitation is another measure that would be beneficial. This includes keeping grain spillage swept up and damaged bags repaired. If these measures were instituted along with poisoning and trapping, then population control would become evident – but it would have to be a continuous effort.

Acknowledgements

We appreciate the help Mohammad Ilyas, Yousaf Khan and Mohammad Nawaz provided in capturing the rats and assisting in the necropsies. We thank Liaqat Ali for entering all the necropsy and morphometric data into the dBASE III computer program. Richard A. Dolbeer and Donald J. Elias, Denver Wildlife Research Center, critically reviewed the manuscript and provided helpful suggestions.

This study was supported with funds provided by the U. S. Agency for International Development under the project "Food Security Management, Vertebrate Pest Control, PASA IPK-0491-P-IF-5017-05". We also thank the Pakistan Agricultural Research Council and the National Agricultural Research Centre, Islamabad, for providing office and laboratory space for the project.

Zusammenfassung

Reproduktionsbiologie und Populationsstruktur von Rattus rattus in Rawalpindi, Pakistan

Die Fortpflanzungsbiologie und Populationsstruktur von *Rattus rattus* wurden in einem Großhandelsmarkt für Getreide und andere Gebrauchsgüter in Rawalpindi, Pakistan, untersucht. Innerhalb von 14 Monaten wurden die Ratten in monatlichen Abständen auf dem Getreidemarkt gefangen. Wir sezierten und untersuchten insgesamt 2327 Ratten, 1175 männliche und 1152 weibliche. Es wurde festgestellt, daß die männlichen Ratten jeden Monat reproduktionsfähig waren ohne bedeutsame, saisonbedingte Unterschiede; weibliche Ratten waren jeden Monat trächtig, und die Trächtigkeitsfrequenz betrug durchschnittlich 39,8 %. Die jeweilige Embryonenzahl während des letzten Viertels der Trächtigkeit betrug durchschnittlich 6,1 ± 1,7 (SD). Auf der Basis unserer Studie von Ratten, die zum ersten Mal trugen, und von Ratten, die schon vorher trächtig waren, kalkulierten wir, daß eine geschlechtsreife weibliche Ratte im Durchschnitt 1,8 Trächtigkeiten hat. Die durchschnittliche Produktion von jungen Ratten war 10,9 pro Weibchen (6.1 × 1.8). Unreife Tiere (unabhängig, aber nicht sexuell reif) dagegen machten 13,1 % der Gesamtstichprobe aus. Nachwuchs war fortlaufend während der Studie vorhanden und wies darauf hin, daß beträchtliche Todesfälle bei Nestlingen und sexuell unreifen Tieren vorkamen. Viele Wunden und Narben an erwachsenen Tieren beider Geschlechter wiesen darauf hin, daß ein hohes Maß von Streit und Aggression zwischen den gesellig lebenden Ratten herrschte.

References

Barnett, S. A. (1963): The rat. A study in behavior. Chicago: Aldine Publ. Co.

Beg, M. A.; Mushtaq-Ul-Hasan, M.; Kausar, S.; Khan, A. A. (1983): Some demographic and reproductive parameters of house rat population in Faisalabad, Pakistan. Pakistan J. Zool. **15**, 83–87.

Blower, L. G.; Cook, L. M.; Bishop, J. A. (1981): Estimating the size of animal populations. London: George Allen and Unwin Ltd.

Brooks, J. E.; Ahmad, E.; Hussain, I. (1987): Rat population and stored food losses at a Pakistan grain market. Vertebrate Pest Control Project, National Agricultural Research Centre, Islamabad, Pakistan: Technical Report No. 12 (unpubl.).

Davis, D. E. (1964): Manual for analysis of rodent populations. Penn. State Univ., University Park, Penn.

Harrision, J. L. (1952): Reproduction in rats of the subgenus *Rattus*. Proc. Zool. Soc. Lond. 121, 674–694.

Rana, B. D.; Advani, R.; Soni, B. K. (1983): Reproductive biology of *Rattus rattus rufescens* in the Indian desert. Z. Angew. Zool. 70, 207–216.

Southwick, C. H. (1966): Reproduction, mortality and growth of murid rodent populations. In: Indian Rodent Symposium, 1966, Calcutta. Calcutta: Johns Hopkins University Centre for Medical Research and Training.

Taber, R. D.; Sheri, A. N.; Ahmad, M. S. (1967): Mammals of the Lyallpur Region, West Pakistan. J. Mammalogy **48**, 392–407.

Authors' addresses: Joe Brooks, USDA/APHIS/ADC/Denver Wildlife Research Center, P. O. Box 25266, Denver, Colorado 80225-0266, USA; Ejaz Ahmad, Department of Fishery and Wildlife Biology, Colorado State University, 135 Wagar Building, Fort Collins, Colorado 80523, USA; and Iftikhar Hussain, Vertebrate Pest Control Laboratory, National Agricultural Research Centre, Park Road, Islamabad, Pakistan